Jet Propulsion Laboratory
California Institute of Technology

Co-op 2017 Final Presentation by Hao Tang

Mars 2020 RSM & Chassis

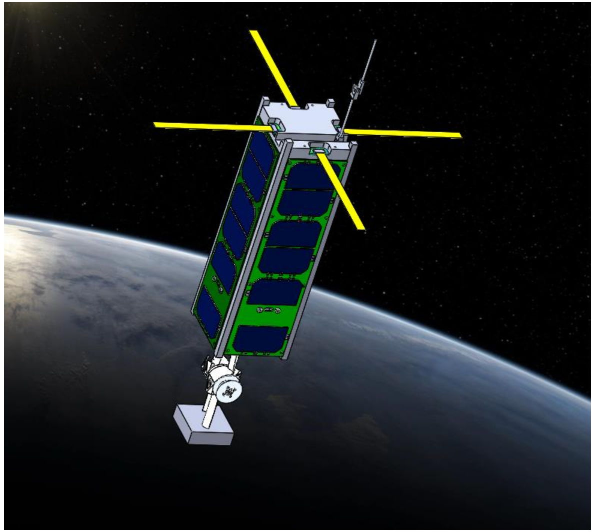
352C – Mechanical Structures and Articulation, Presented by Hao Tang, Jet Propulsion Laboratory, California Institute of Technology, 08/17/2017

Agenda

- About me
- Recap of Remote Sensing Mast (RSM) Work
- Tidbits here and there
- Chassis Structural and Thermal Bracket Analysis

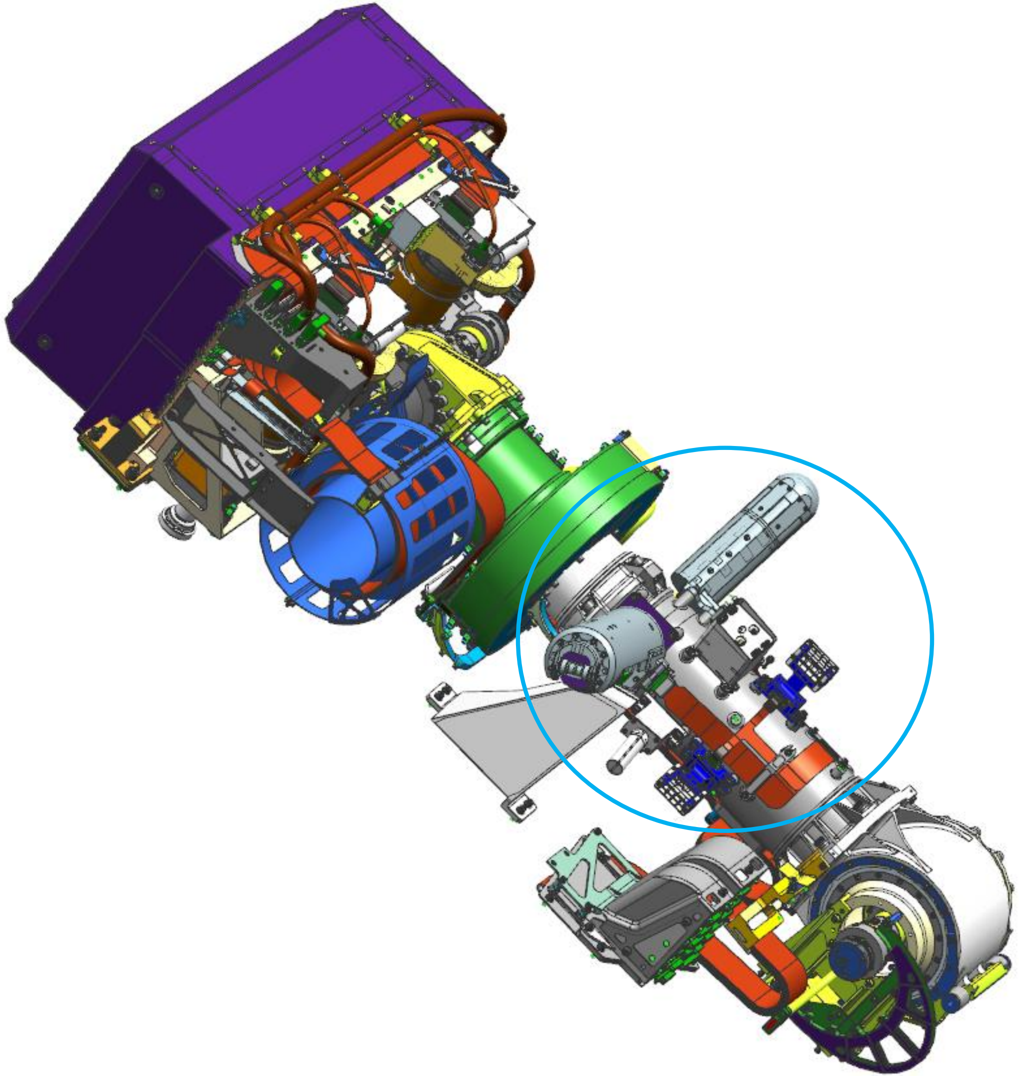
Me!

Michigan Marching Band



Plasma Electrodynamics CubeSat

Hiking!



Mars 2020 Remote Sensing Mast

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Context

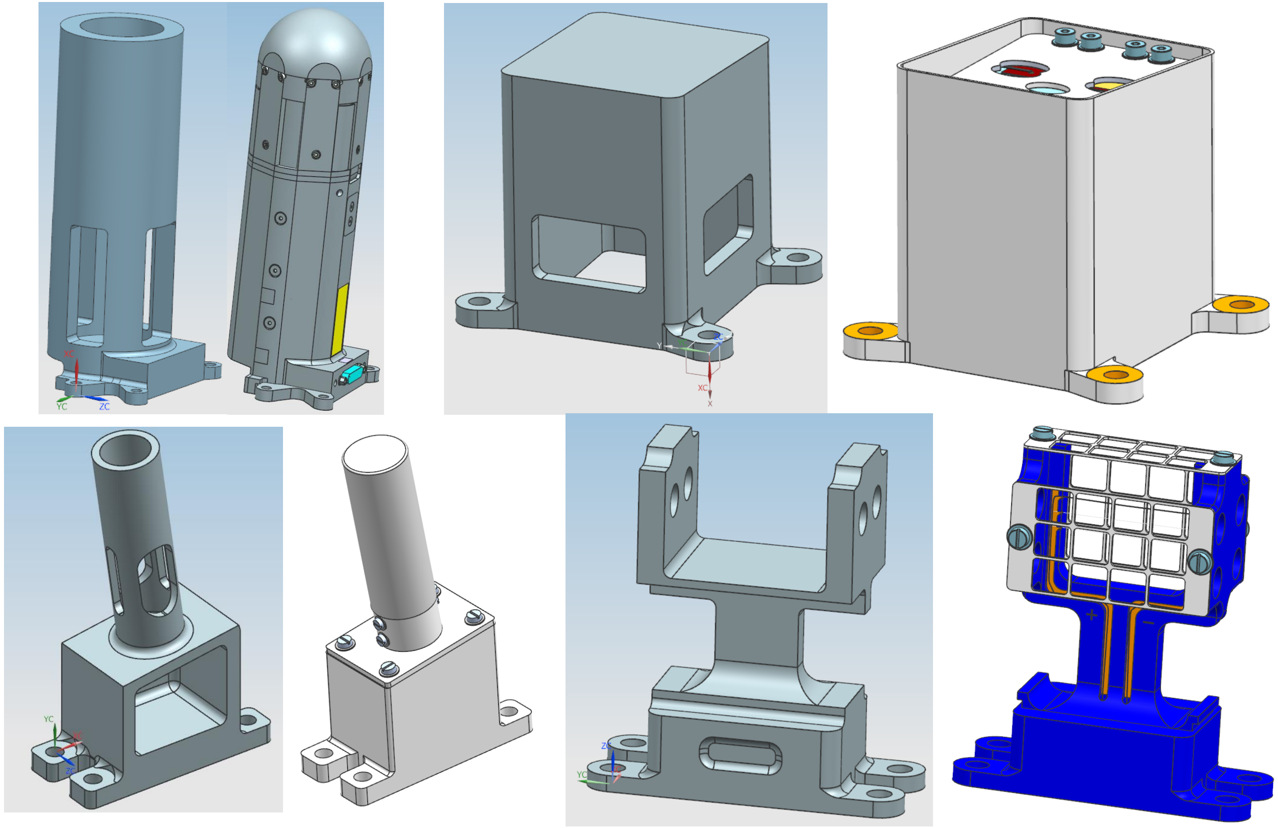
- Flight instruments are arriving late in testing campaign schedule
- Project needs stand-ins (mass models) for system practical tests
- My task: create the MEDA mass models
- Testing
    - TVAC (individual mass models)
    - Centrifuge, sine, modal (rover with RSM on it)

Summary of MEDA Mass Models

Right = flight

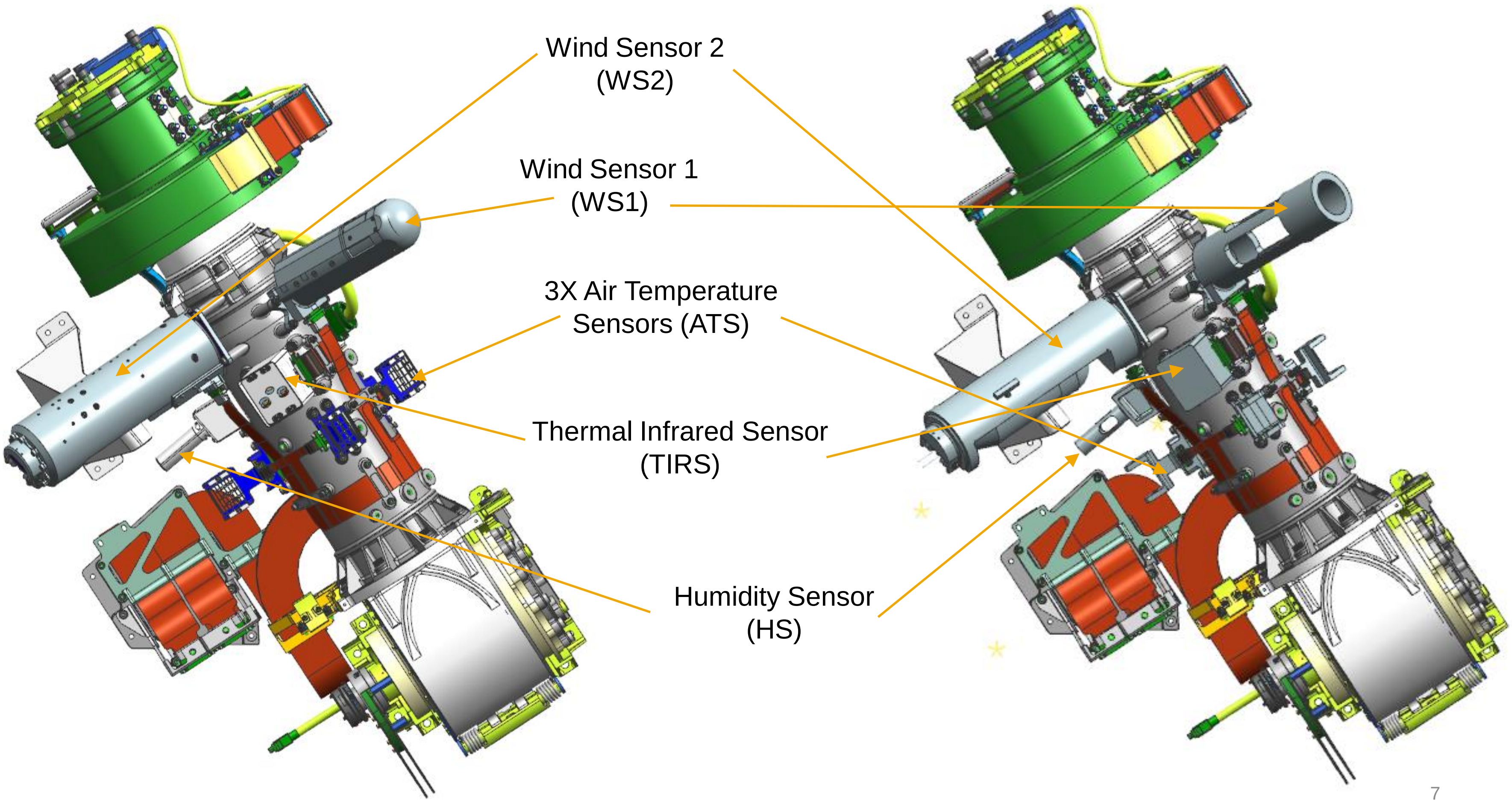
Left = mass model

- All margins were above 2
- Mass & CG all within 5% flight
- Low cost manufacturability
- Within NTE boundaries



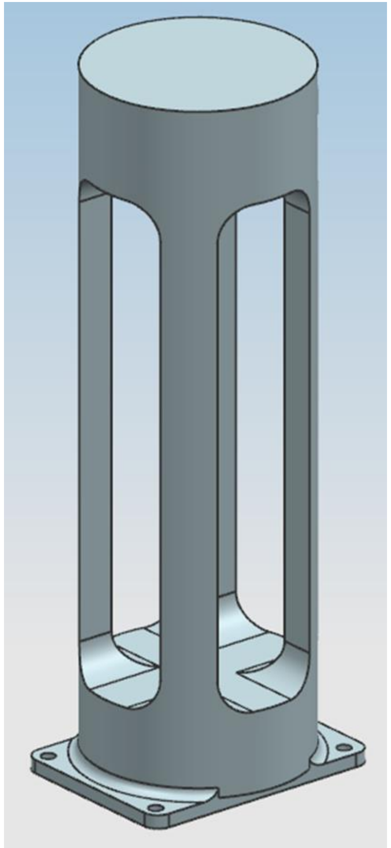
Flight

Mass Models

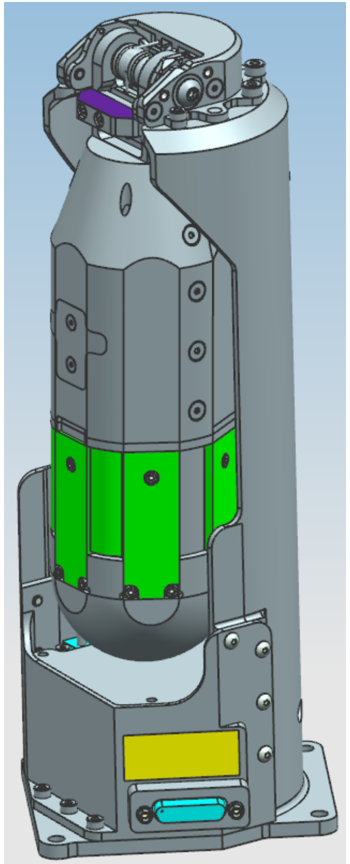


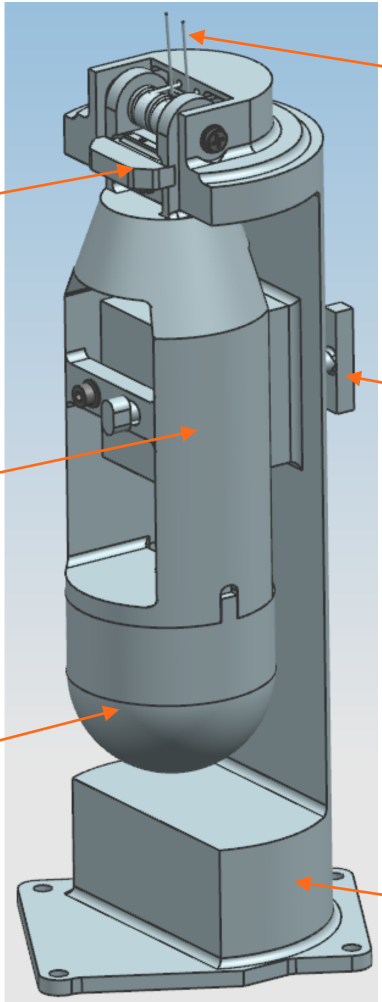
Wind Sensor 2 – Mass Model Only

WS2	Mass Model	Actual	Difference	% Error
X	96.5 mm	97.2 mm	0.7 mm	0.72%
Y	35.2 mm	34.7 mm	0.5 mm	1.44%
Z	24.8 mm	24.2 mm	0.6 mm	2.48%
Mass	711.39 g	695.78 g	15.61 g	2.24 %



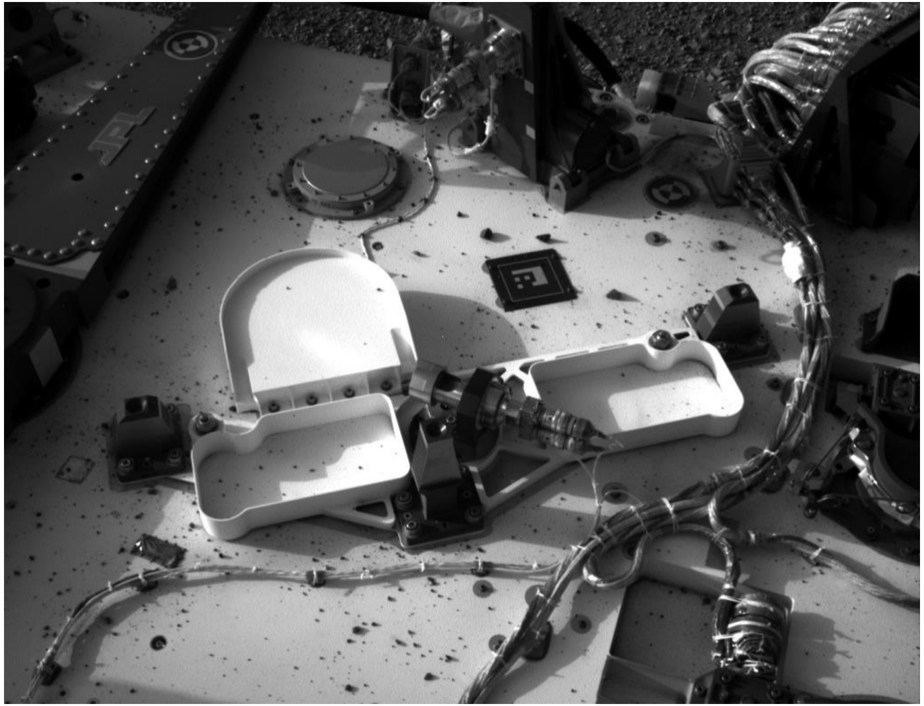
WS2 Deployable Overview





Tidbits here and there

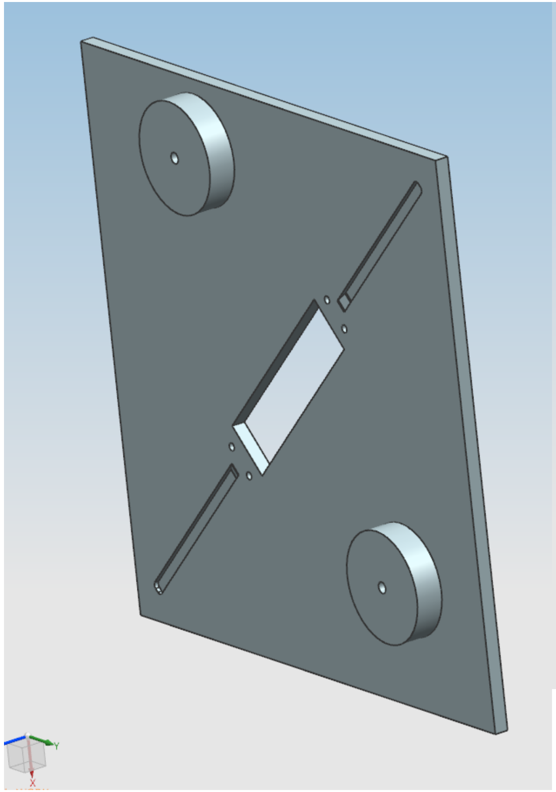
- Fiber Optic Cable (FOC) GSE for Pebble Test
- HEPA Filter Leak Test
- RPFA Housing Epoxy Test (EA 9392 vs Arathane 5753)

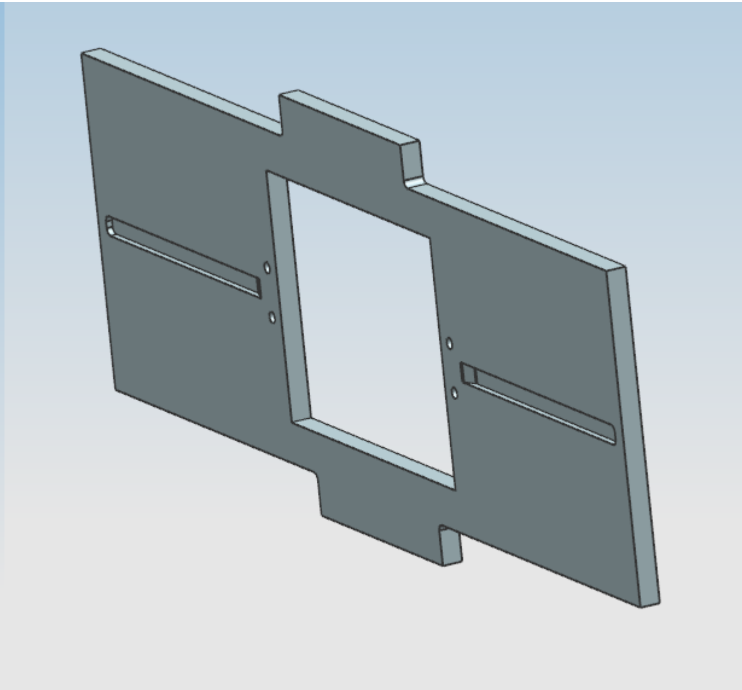


Pebbles on Rover top deck from MSL

Fiber Optic Cable GSE Pebble Test

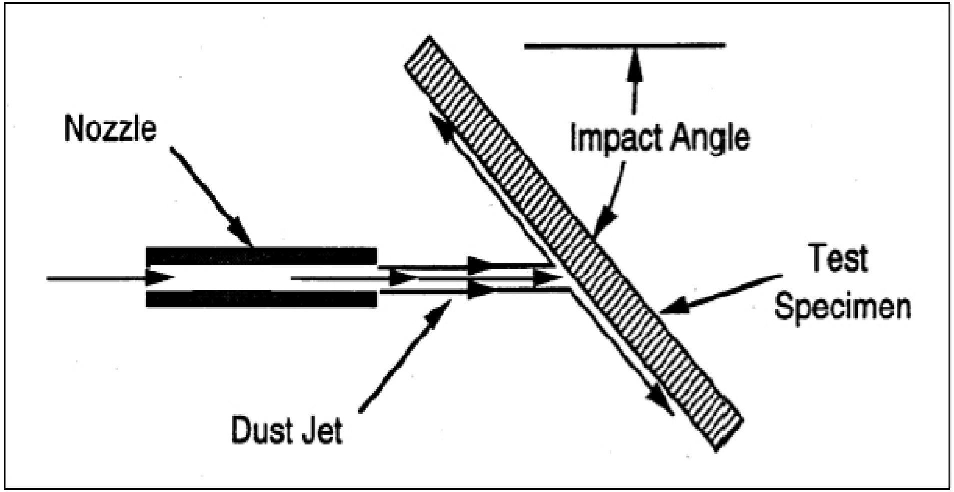
- Need to make observations and test integrity of FOC during EDL

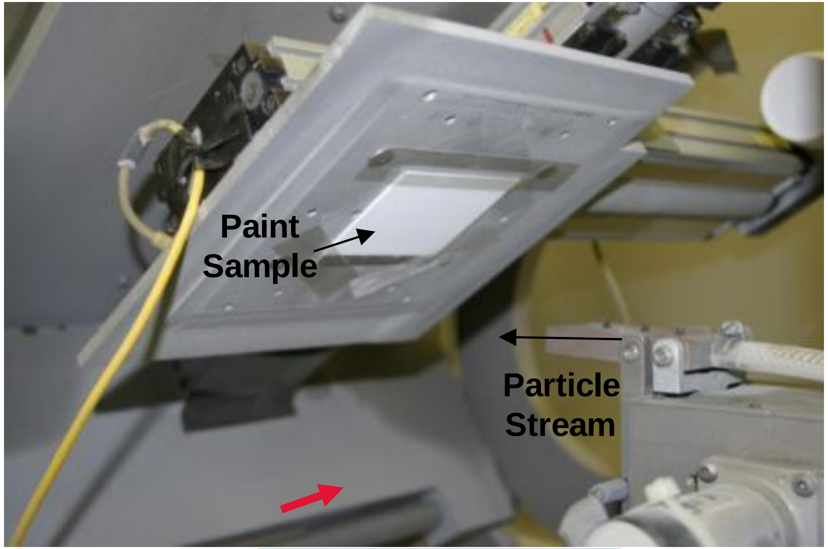


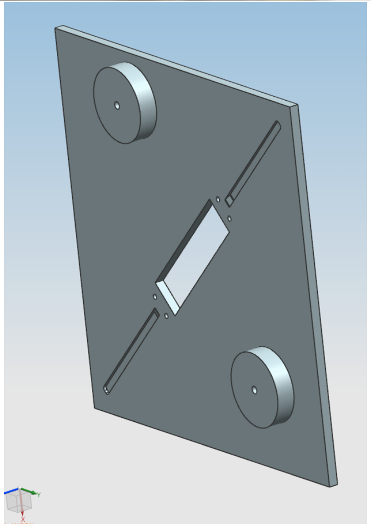


Erosion Rig (Small Particles/Sand)

- Sample Size Max 10”x10”

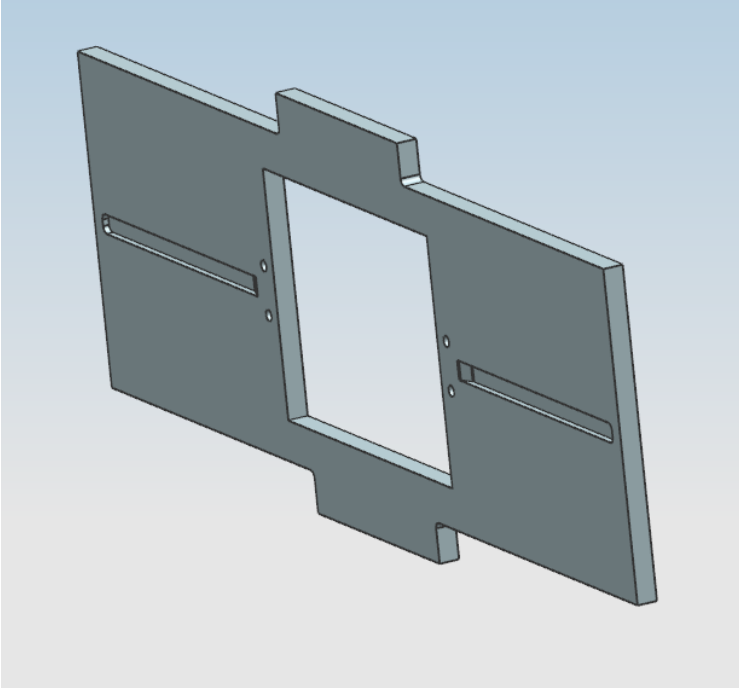




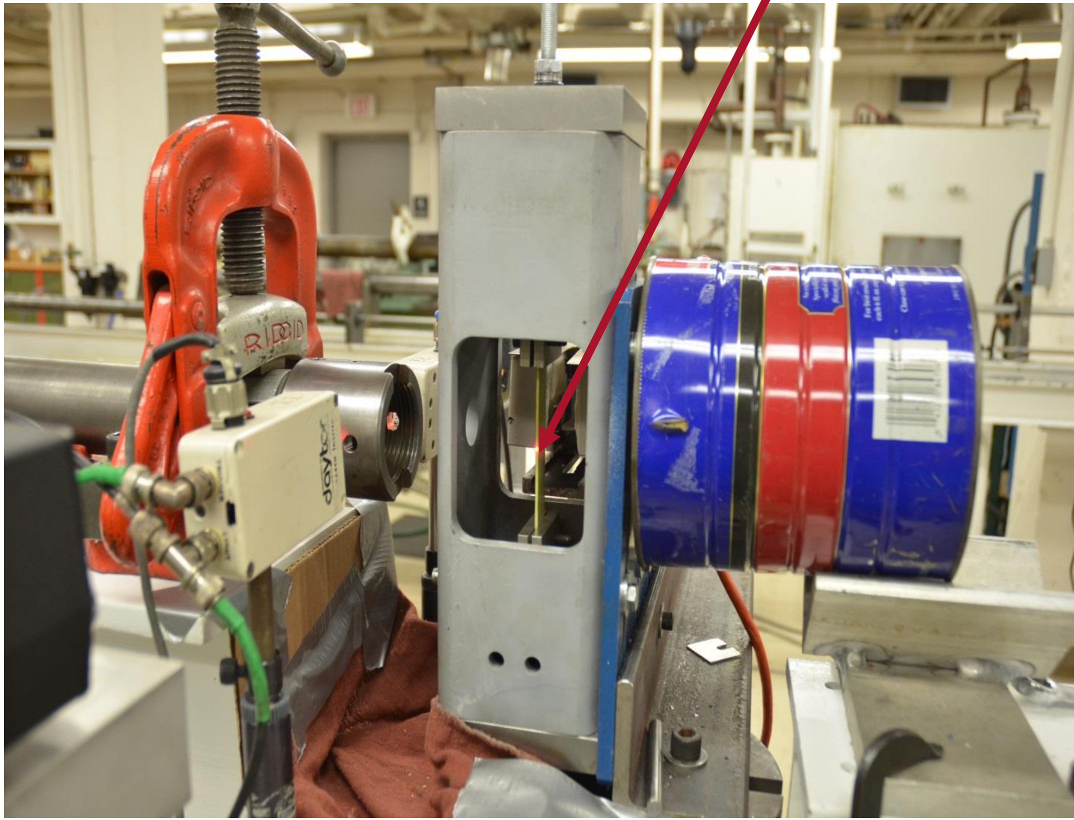


Gas Gun (Large Particles)

- Sample size 3”x5”



Sample



HEPA Filter Leak Test – Chassis and RSM Filters

- Using same filters for M2020 & want to make sure MSL HEPA filters still functional
    - Baseline measurement of # of particles in room
    - Cleaning
    - Actual Test
        - <=.03% Baseline = Pass
- After passing, part set up for another test to model failure modes of filter due to pebble test
- Both passed leak tests and will be sent for pebble tests
- Another leak test after pebble test to see if any changes/leak

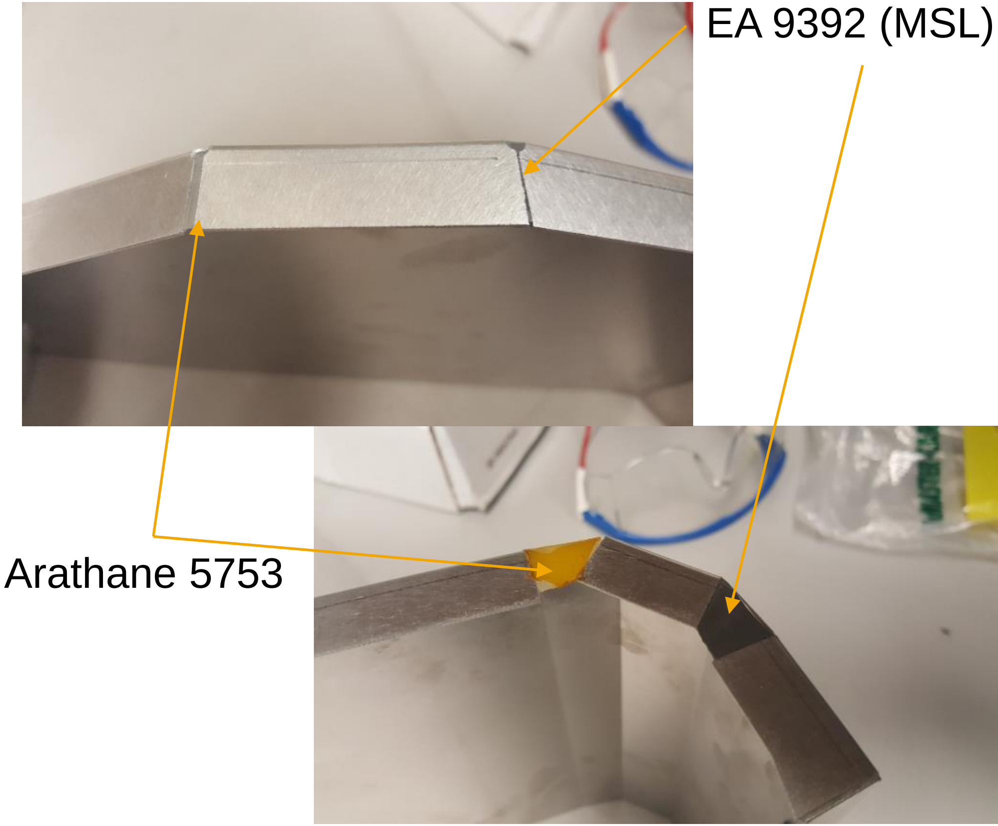
Rover Pyro Firing Assembly (RPFA) Epoxy Test

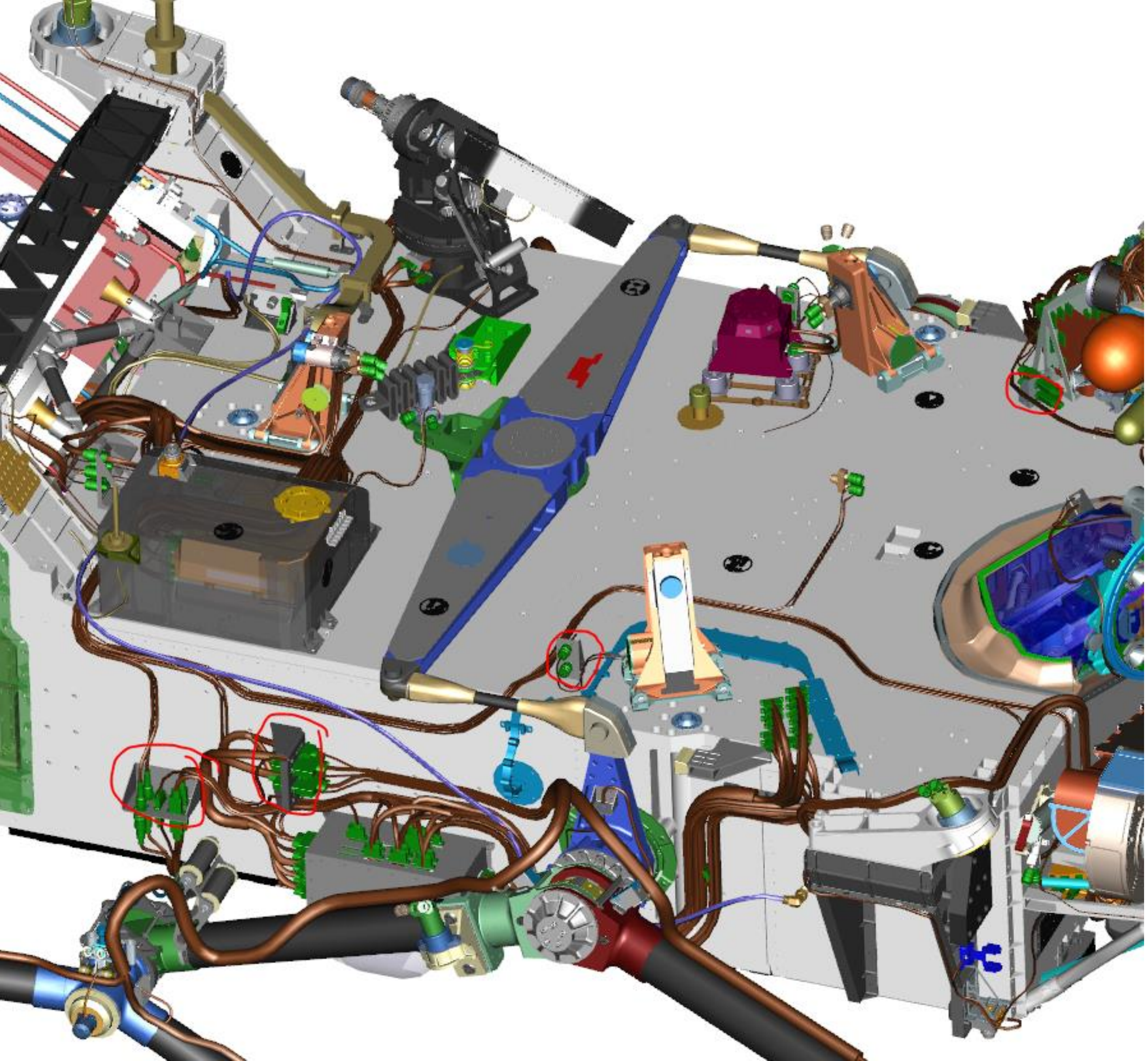
Context

- RPFA needs to be kept warm
- Bend relief holes need to be covered
- Wanted to test different adhesives covering holes

Quick Facts

- Epoxy done at room temp
- Quick and dirty
- Strength of epoxy
    - Cracking or fracture
- Next test at colder & hotter temperature





Mars 2020 Chassis Brackets

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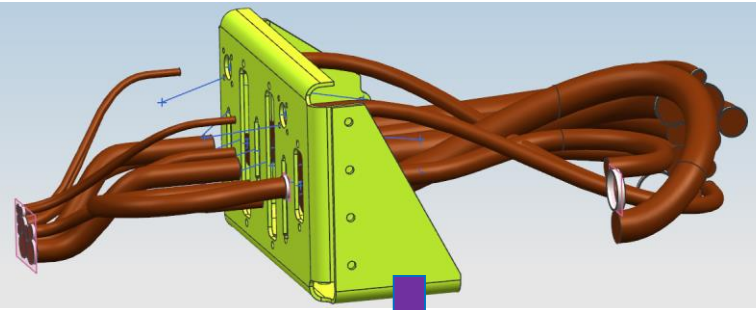
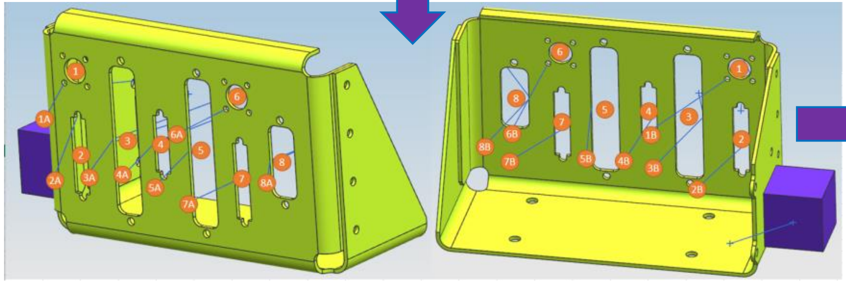
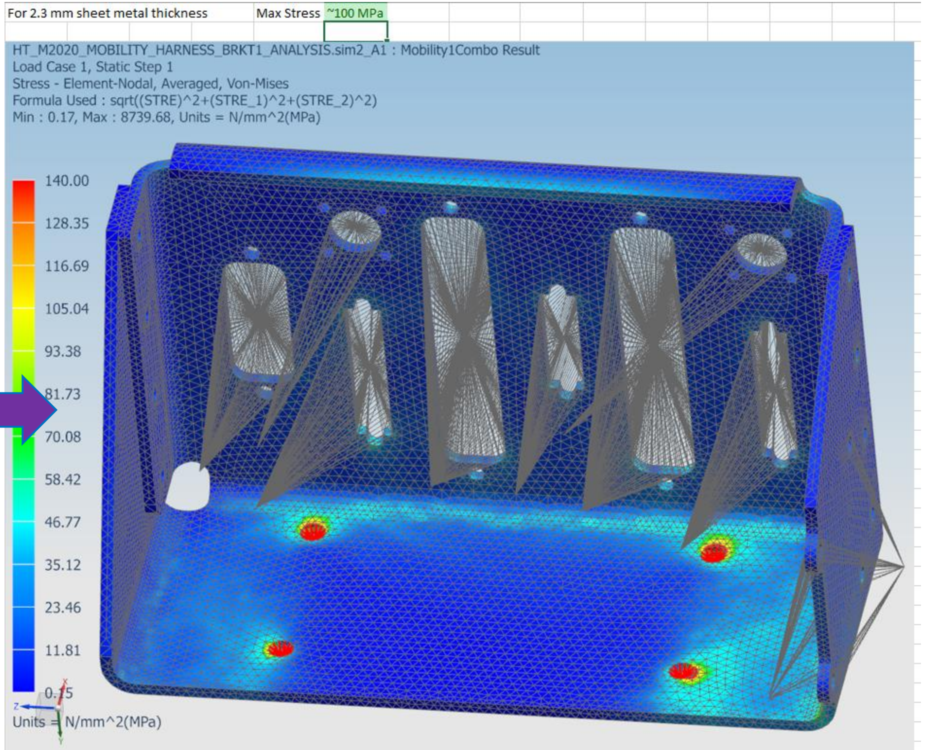
Requirements

- Brackets holding cables are structurally and thermally affected
  - Structurally, needs margin of 2 and 1.6 for ultimate tensile and yield, respectively
    - 100g MAC loads
  - Thermally, temperature differential at least 80 °C
    - High differential = not losing heat quickly
    - 1 Watt of power through cable
- If not meeting margins, design change is necessary
  - Trying to keep material 6061, which is cheaper and easier to machine
  - Not always a complex change

Structural Analysis Example & Pictures



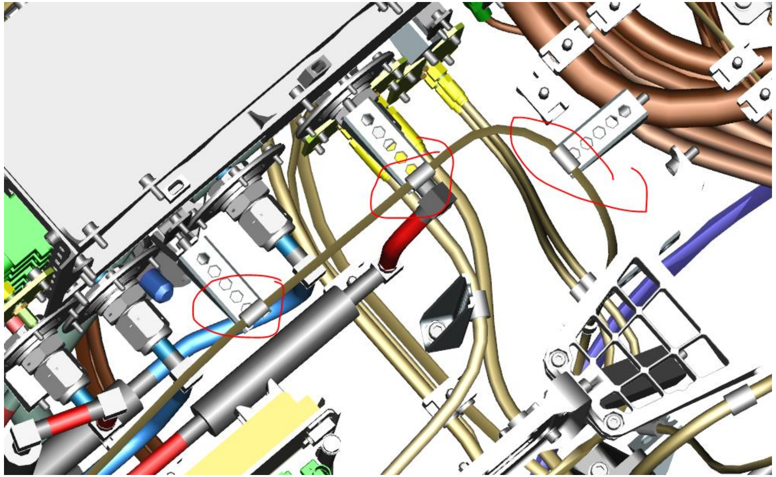


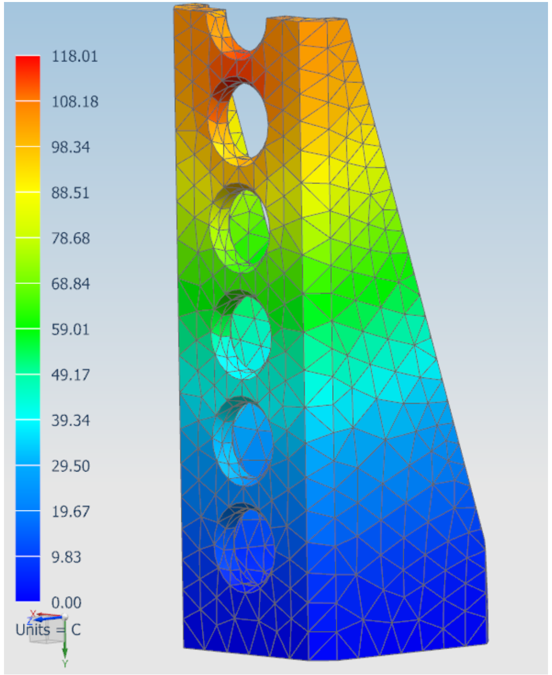


- Other Brackets I did
  - Beg Pyro FJ
  - E-Bridle
  - Heli FJ
  - CBH
  - Telecom
  - Front Hazcam
  - EDL Downlook
  - Cable Saddles

Thermal Analysis Example & Pictures

- Cables inside Rover from hot components need to maintain heat
- Thermal requirement was at least 80 °C/W
  - Applied 1 W through cable





Lessons Learned

- RSM Mass Models
  - Design for Manufacturability
- Testing
  - Finding unique solutions given hard constraints
  - Epoxy and Adhesive properties
- Chassis Brackets
  - Better understanding of MAC loads
  - Better understanding of setting up structural analysis

Special Thanks To…

- Zach Ousnamer
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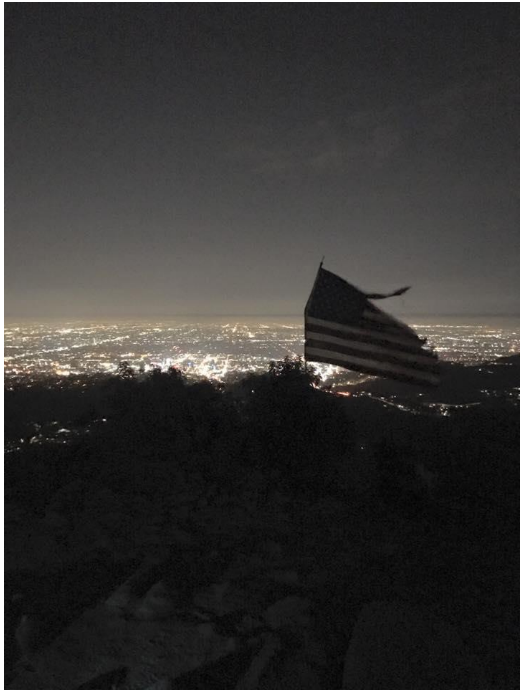
- Emma Bradford
- Jen Knight
- Yuki Salinas
- Lori Siraishi
- Diane Tan

Questions?



Wisdom Tree hike @ Griffith Park

JPL!

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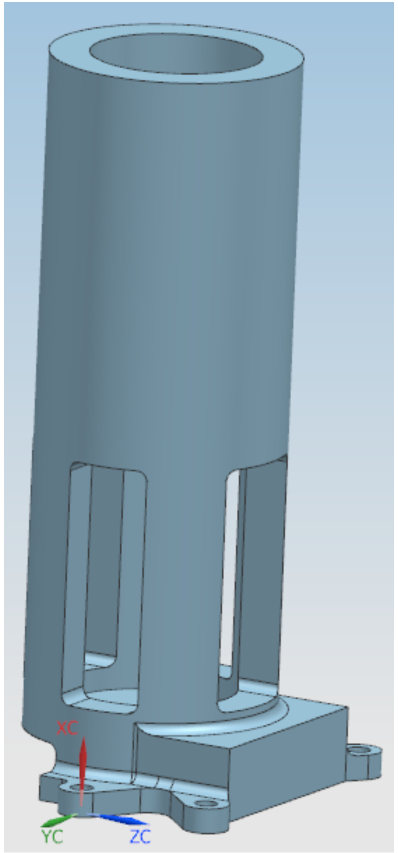
Matching Mass & Center of Gravity

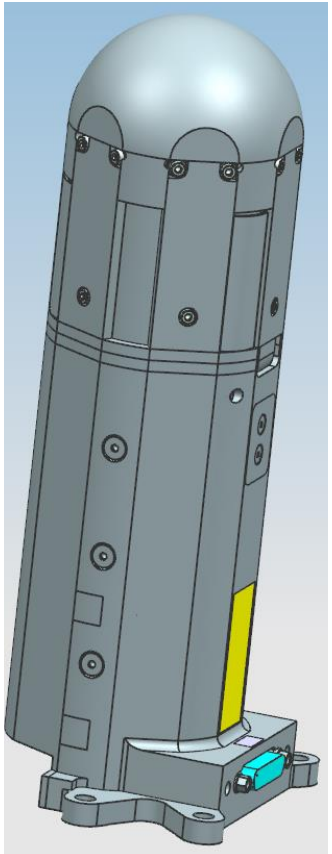
General Requirements

1. Parts must have
    1. Masses +10%/-5% within flight model values
    2. CG +/-10% within flight model values
2. Structurally sound design
3. Low-Cost Manufacturability
4. Be within NTE boundaries
5. Match flight hardware tolerance at interfaces
    1. Stay as close to flight boundary as possible

Wind Sensor 1

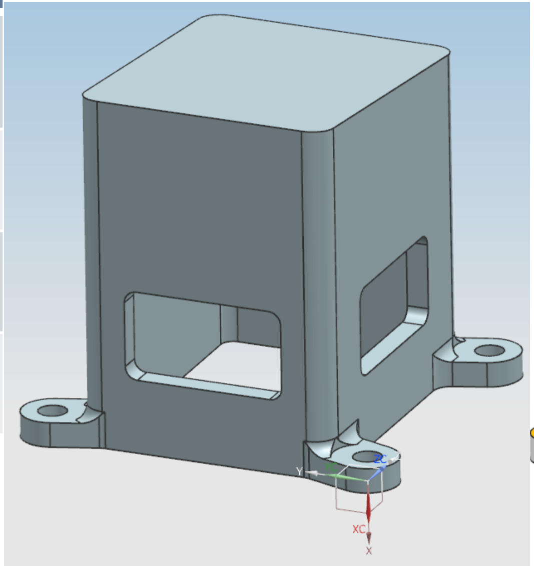
WS1	Mass Model	Actual	Difference	% Difference
X	71.0 mm	70.9 mm	0.1 mm	0.14%
Y	-33.0 mm	-33.0 mm	0 mm	0%
Z	-2.29 mm	-2.4 mm	0.11 mm	4.58%
Mass	362 g	360 g	2 g	0.56%

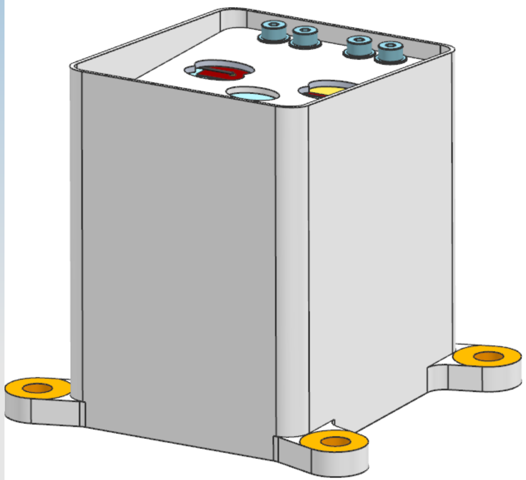




Thermal Infrared Sensor

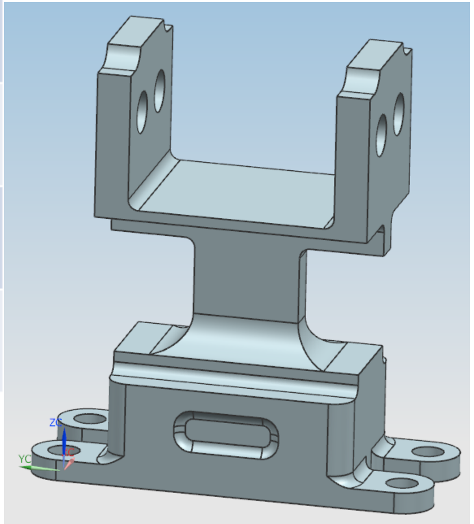
TIRS	Mass Model	Actual	Difference	% Error
X	-32.938 mm	-32.341 mm	0.597 mm	1.85%
Y	26.883 mm	27.021 mm	0.138 mm	0.51%
Z	23.341 mm	23.391 mm	0.050 mm	0.21%
Mass	117 g	110 g	7 g	6.36%

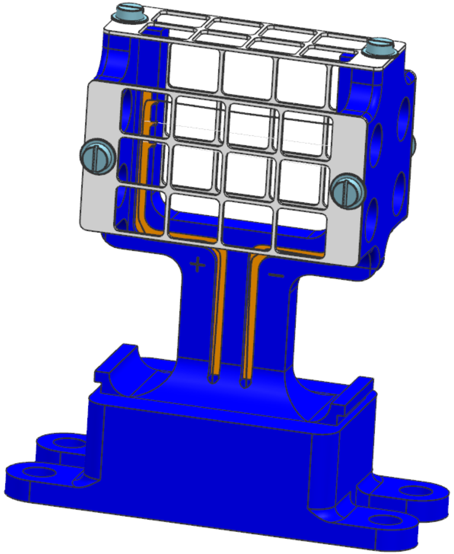




Air Temperature Sensor (Fiberglass)

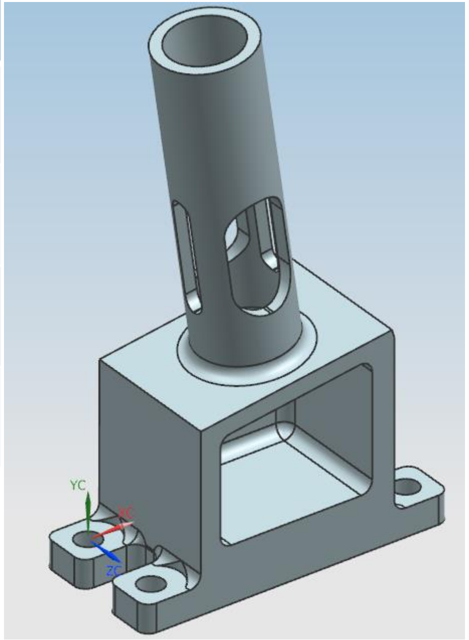
ATS	Mass Model	Actual	Difference	% Error
X	7.24 mm	7.24 mm	0 mm	0%
Y	-24.20 mm	-24.20 mm	0 mm	0%
Z	20.37 mm	19.78 mm	0.59 mm	2.98%
Mass	59 g	56 g	3 g	5.36%

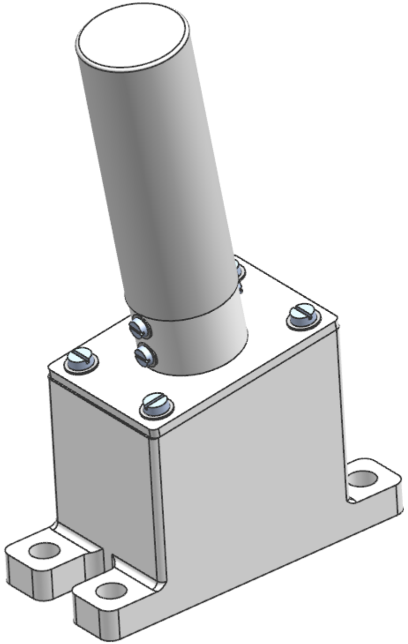




Humidity Sensor

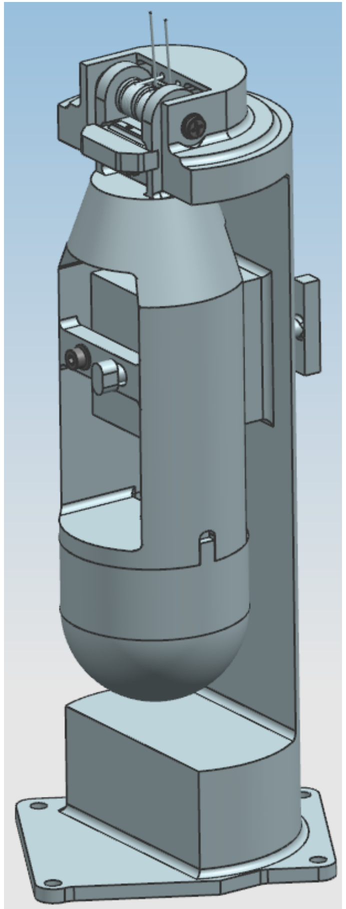
HS	Mass Model	Actual	Difference	% Error
X	22.74 mm	22.66 mm	0.08 mm	0.35%
Y	17.50 mm	17.93 mm	0.43 mm	2.40%
Z	6.67 mm	7.05 mm	0.38 mm	5.39%
Mass	61 g	60 g	1 g	1.67%





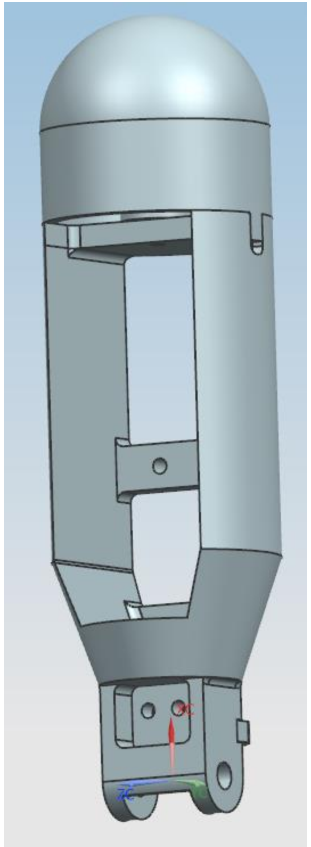
Simple Static

- Only needed Boom to have similar mass and CG as flight



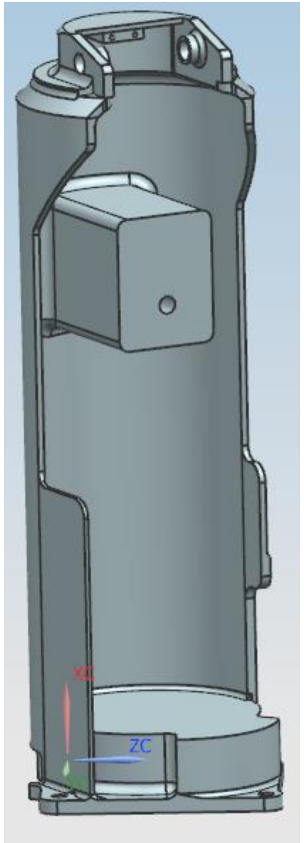
Wind Sensor 2 – Boom Only

WS2	Boom Mass Model	Boom Actual	Difference	% Error
X	88.2 mm	89.3 mm	1.1 mm	1.23%
Y	1.31 mm	1.44 mm	0.13 mm	9.02%
Z	-.05 mm	0 mm	0.05 mm	N/A
Mass	213.28 g	197.78 g	15.5 g	7.83%

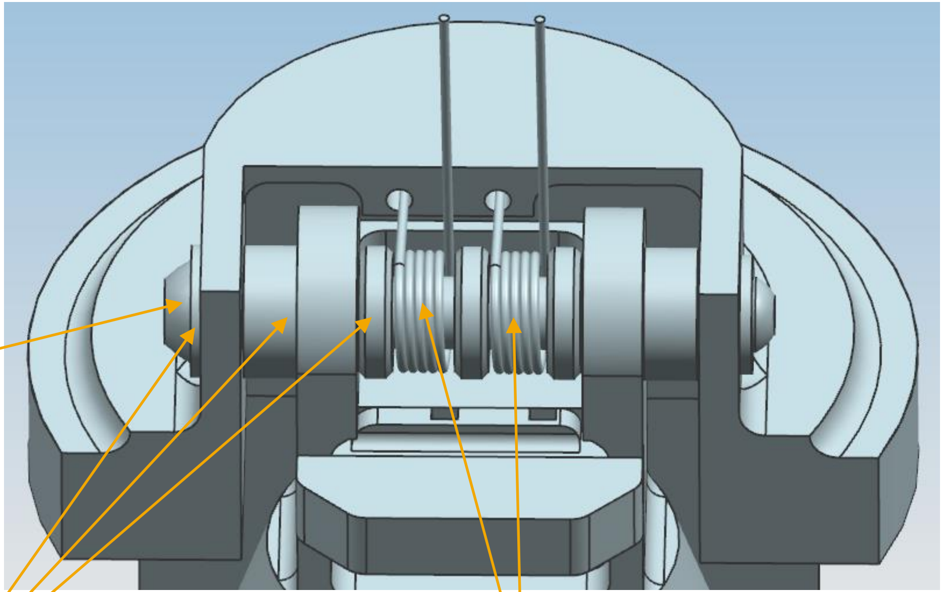


Wind Sensor 2 – Static Only

WS2	Static Mass Model	Static Actual	Difference	% Error
X	83.9 mm	83.1 mm	0.8 mm	0.96%
Y	31.5 mm	31.4 mm	0.1 mm	0.32%
Z	22.6 mm	22.5 mm	0.1 mm	0.44%
Mass	501 g	498 g	3 g	0.60%

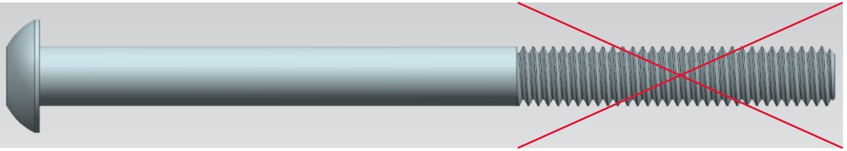


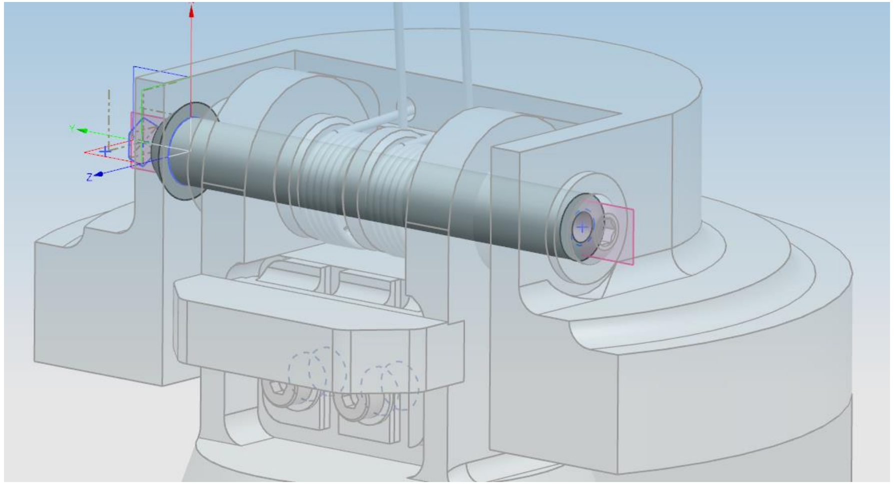
Hinge Area Overview



Custom Shaft

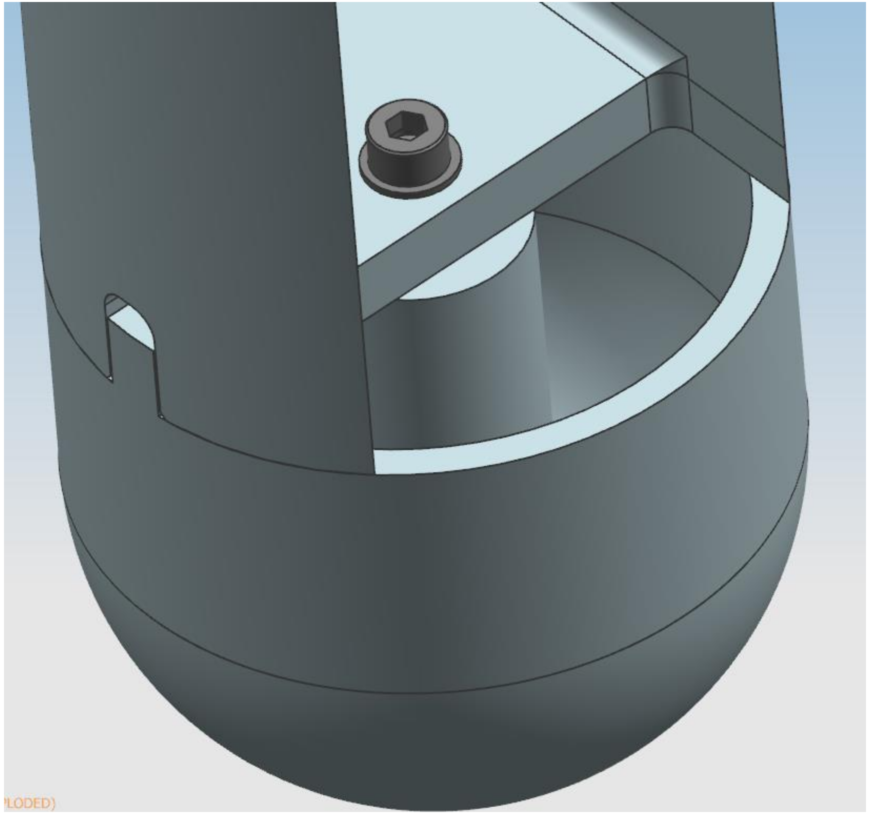
- Threaded shaft for aesthetics
- Guarantees threads won’t negatively impact rotation





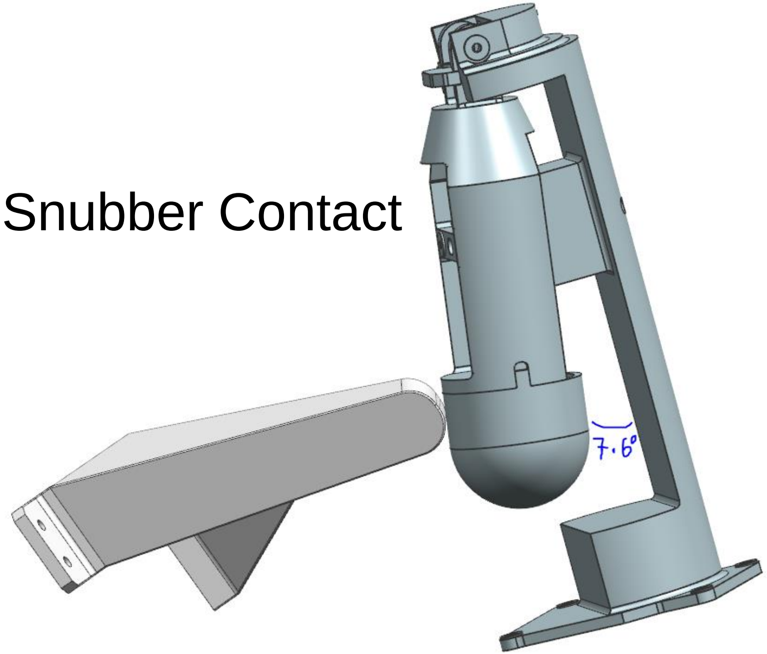
Locking Mechanism

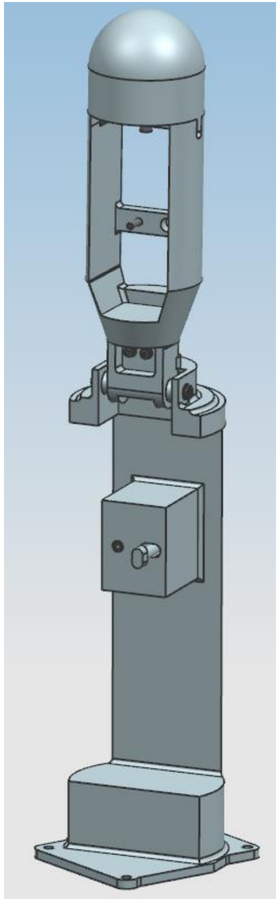
- Extremely difficult to machine if the Boom just one piece
- Created two pieces
  - Boom cap needed to combine with Boom body to match CG & mass without risk of rotation



Deployed Wind Sensor 2

Snubber Contact





Simulation

Methods: FEA Acceleration Loading

$$A_x = T_x + R_y D_z + R_z D_y$$
$$A_y = T_y + R_z D_x + R_x D_z$$
$$A_z = T_z + R_x D_y + R_y D_x$$

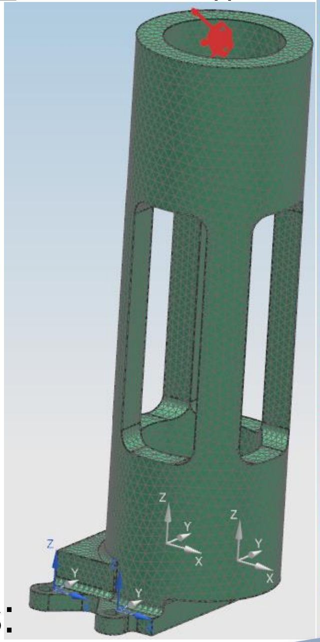
A_i = Resolved acceleration along i direction
T_i = Translational acceleration in i direction
R_i = Rotation acceleration about i direction
D_i = Moment arm length along i direction

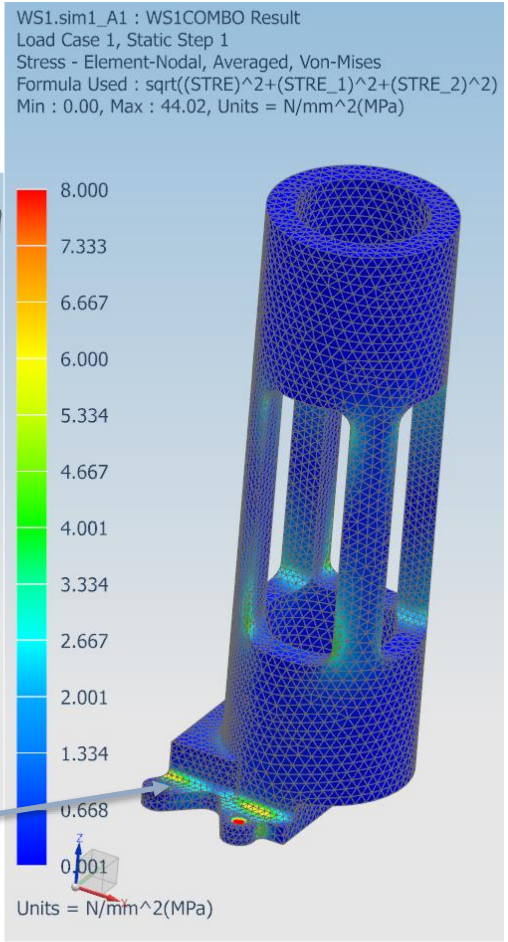
- Each resolved acceleration is the combination of a translational and two orthogonal rotational contributions.
- Distance vector from CG to geometric center of bolt pattern used as moment arm for rotational contributions.
- Magnitudes used for all values.

Wind Sensor 1

Yield Margin: 7.2
Ultimate Margin: 6.1

+X





Accelerations:
- X – 5.18 gs
- Y – 5.27 gs
- Z – 15.63 gs

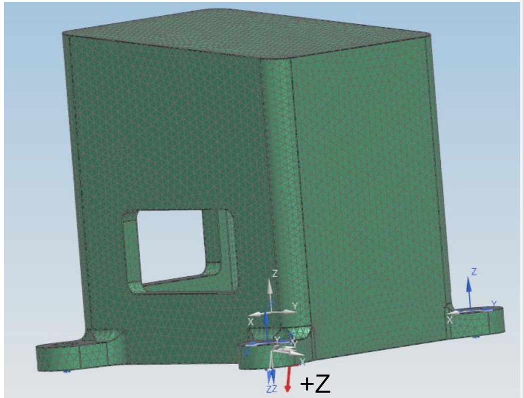
Max Stress:
14.13 Mpa
2.05 ksi

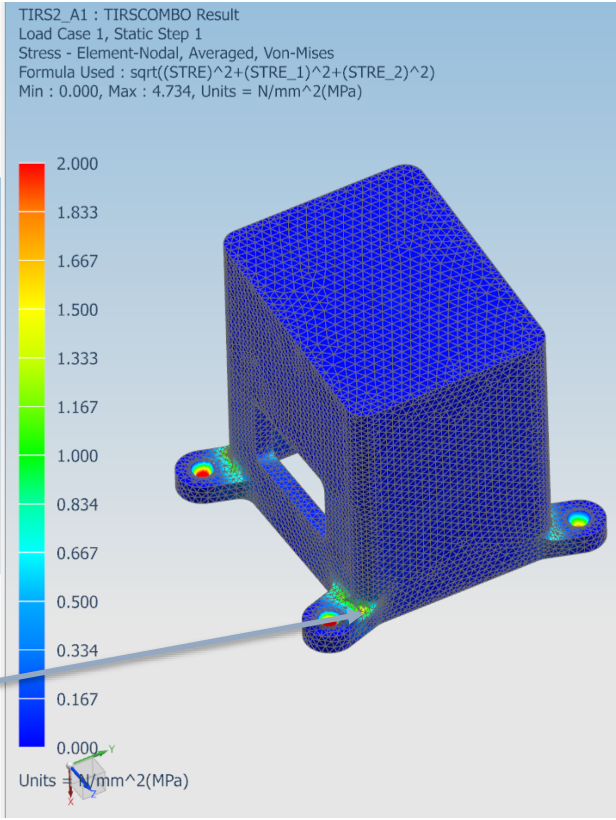
Thermal Infrared Sensor

Yield Margin: 40.7
Ultimate Margin: 35.4

Accelerations:

X – 4.4996 gs
Y – 4.9012 gs
Z – 15.1092 gs



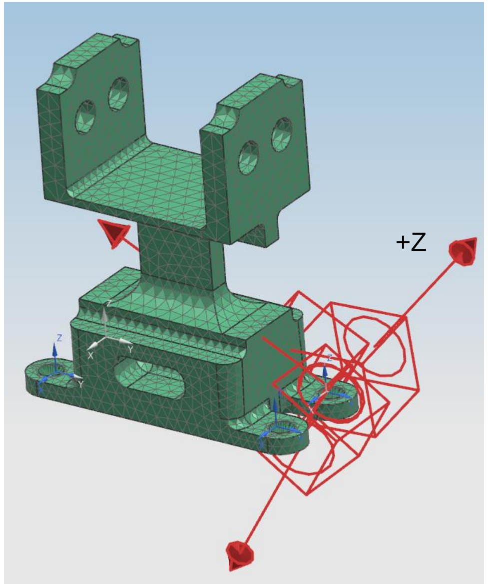


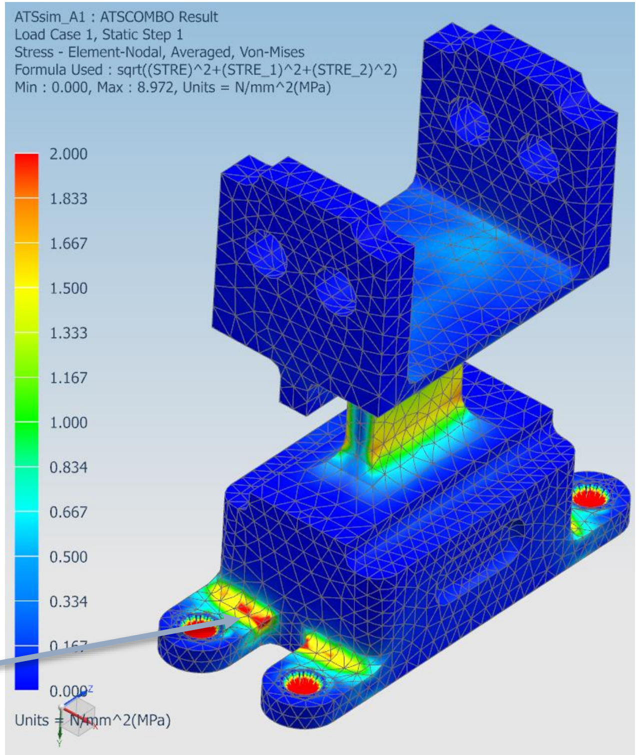
Max Stress:
1.46 MPa
0.21 ksi

Air Temperature Sensor

Yield Margin: 22.8
Ultimate Margin: 19.5

Accelerations:
- X – 4.109 gs
- Y – 4.658 gs
- Z – 15.219 gs

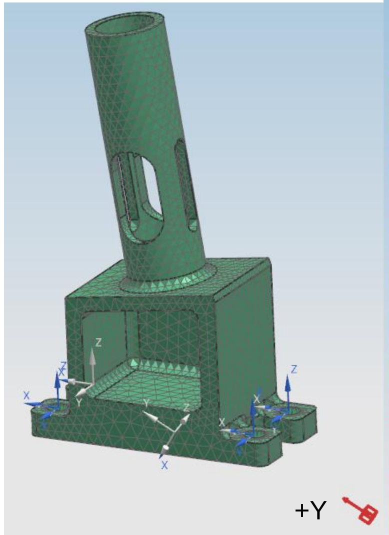


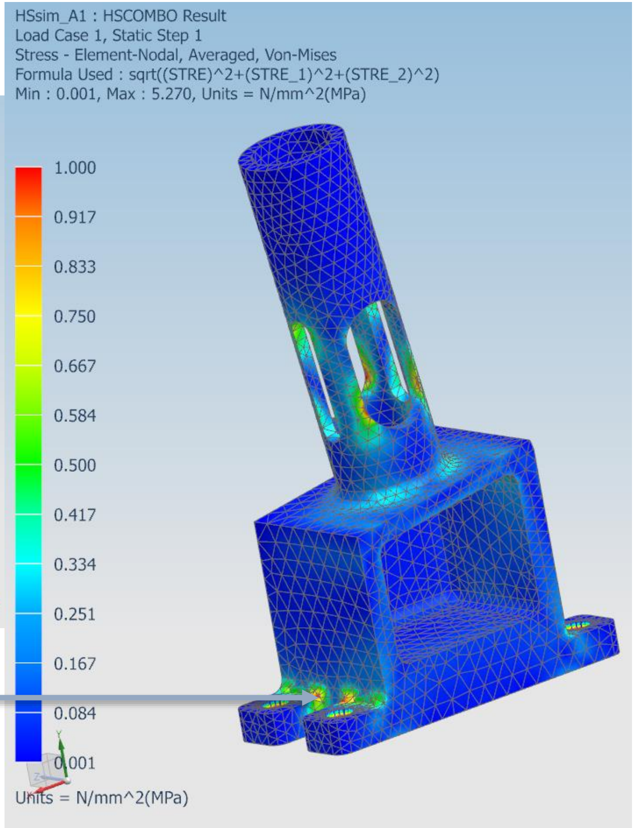


Max Stress:
3.09 Mpa
0.45 ksi

Humidity Sensor

Yield Margin: 59.2
Ultimate Margin: 51.5





Accelerations:

X – 3.9327 gs
Y – 4.385 gs
Z – 15.2391 gs

Max Stress:
1.35 Mpa
0.196 ksi

Wind Sensor 2

Yield Margin: 3.0
Ultimate Margin: 2.6

Accelerations:

- X – 4.7744 gs
- Y – 5.4856 gs
- Z – 16.0356 gs

Max Stress:
22.03 MPa
3.20 ksi